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Mode S TRANSPONDERS TEST BENCHES USER REQUIREMENTS (version 1)

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This note presents user requirements for test tools for Mode S (and Mode A/C) transponders.
Past experiences in transponder verification, mandatory maintenance rules are shown; a first series of tests is developed for what should be a common Ramp Test bench.
A next note will develop the tests for a Laboratory unit, conceived as an extension to this Ramp version.

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Mode S TRANSPONDERS TEST BENCHES USER REQUIREMENTS (version 1)

by

Michel BIOT

Summary

Ramp test equipment for Mode A/C transponders exist at present, but generally perform only the mandatory tests to assure the safe behaviour of these avionics.

There is a need for standardised test tools, that would execute defined sets of measurements in defined test conditions so as to give comparable results for Mode A/C and Mode S transponders.

A Ramp version would be necessary for maintenance, and a Laboratory version for repair and research and development .

Based on multiple experiences of transponder performance measurements, as well as on actual test tools, the present paper develops the test needs for both versions, followed by the user requirements for the Ramp version that could be accepted as a base for technical specifications.

The user requirements for the Lab version will follow in the second version.

LIST of ACRONYMS and ABBREVIATIONS

ADLP	Aircraft Data Link Processor
BDS	Binary Data Store : subfield in MB downlink field
BDS x,x	now renamed GICB register x,x
CMC	Central Maintenance Computer (of the aircraft)
CMS	Central Maintenance System (of the aircraft)
GDLP	Ground Data Link Processor
GICB	Ground Initiated Comm B
GTVS	Ground Transponder Verification System
MOPS	Minimum Operating Performance Specifications (of the Transponders, edited by EUROCAE)
STFTV	Surveillance team Task Force for Transponder Verification
TCAS	Traffic alert and Collision Avoidance System
XPDR	Transponder (Mode A/C and Mode S)

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1 Preamble : PRESENT SITUATION & NEEDS

1.1 THE TOOLS

Figure 1 : Laboratory bench for XPDR & ADLP

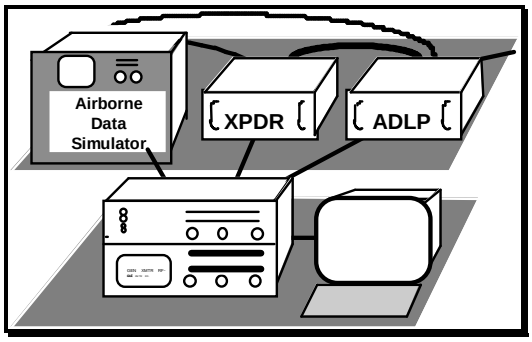
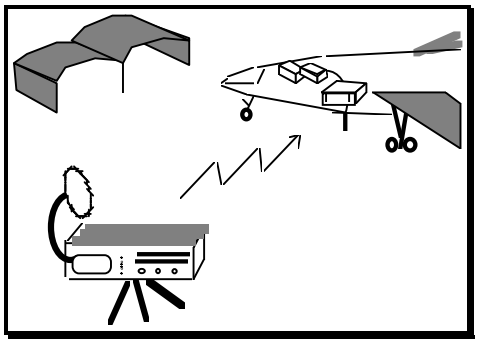


Figure 2 : Ramp tester for Airborne chain



1.2 THE REASONS

1.2.1 References

We refer mainly to an information paper called "Off-line tools for Airborne Equipment" (see reference 1) developed by DED.3 dated Feb 96, philosophy in support of the IIMSES requesting a coherent bench policy for these equipment, compatible with the future ATN.

Concerning the measurements to be executed in Mode A/C, the following documents are also used:

- the GTVS (Ground Transponder Verification System) feasibility (see ref 2 & 3)
- the STFTV (Task Force on Transponder Verification) (see ref 4)
- an FAA report " Field Study of Transponder Performance in General Aviation Aircraft " (see ref 5).

1.2.2 Laboratory tests

Several test benches exist for Mode A/C but new bench tools are needed for Mode S XPDRs :

- to analyse new errors,
- to investigate new problems, new developments,
- to examine protocols,
- to help certify the airborne installation.

1.2.3 Ramp tests

Several ramp test sets exist for Mode A/C & Mode S but

- they are outdated,
- they are not yet adapted
  - to rapid testing of protocols,
  - to the increased set of tests (data link functions).

1.2.4 Concerning tests in both situations

- Data link function that add new domains of investigation that are only partially fulfilled
- European Harmonisation is necessary for both tools and maintenance requirements (for Mode A/C & S airborne equipment) based on the same EUROCAE MOPS.

1.3 THE LABORATORY TEST BENCH

1.3.1 A need for aeronautical administrations research and technical services

In support of the Initial Implementation Mode S Enhanced Surveillance Programme (IIMSES) which requests a coherent policy be developed for bench testing of airborne equipment;

Data link, ADLP, TCAS, CMS developers in various European industries may take advantage of the availability of such a common instrument.

Existing test benches either measure only Mode A/C & S electric characteristics or some protocol but always off-line. The proposed bench go further in testing systematically all electric parameters and protocols on-line, giving way to up-down sequences, each reply influencing the next interrogation; these protocols include Comm A, B, C & D messages.

1.3.2 Test set-up for a complete test bench

Basically, the tests will be executed on the bench, but finally a ramp installation is necessary to validate " in situ " the complete airborne chain (incl. antenna), that is, with TCAS, CMC,.. in a real environment " on the ground " or, simulated, " in the air ".

For this purpose, some extension towards ramp use (power, antenna, physical support) has to be envisaged. In addition to this operational validation, acceptance of the maintenance procedures will also use this variant.

Finally, mixed installations, combining a specific laboratory with the bench, and a connected ground station can be use to investigate special or new problems. A setup of this kind exist already between the EEC and French and UK technical services.

1.3.3 Objectives of the bench

- validation of SARPS;
- validation in view of equipment certification (not the certification itself);
- validation for maintenance before delivering certificate of conformity and to prepare the maintenance procedure to be adopted for each version of airborne set-up;
- new investigations & operational evaluations.

1.3.4 Test conditions

- Testing is based on ICAO Annex 10, the relevant RTCA & EUROCAE MOPS (signals in space - reply capability - messages exchange protocols - test conditions).
- Altough some equipment will be connected to the XPDR & ADLP, they will not be tested by the proposed tool, they are only in and output to XPDR & ADLP (e.g. they could be replaced by a bench controled airborne data simulator), but the validity of the complete chain will be tested.

1.4 THE RAMP TEST BENCH

1.4.1 A need for aircraft operators (maintenance services)

Existing Ramp test sets are more or less outdated and cannot support all the requirements of

- complete set of Mode A/C tests
- all Mode S protocols
- squitter and long squitter validations

and the economy of fast and automatic testing.

1.4.2 A need for administrations (technical services)

The administartions must control

- the validity of the proposed maintenance requirement
- the execution of this maintenance.

They need also a mixed form of testing, for validation of different equipment in a pseudo-real environment; a set-up of this kind exist presently but this subset is not the purpose of the present document.

1.4.3 Objectives of the bench

The first objective being the testing in real conditions of Enhanced Surveillance transponders, the RAMP test bench has to be developed first, the laboratory equipment being an extension of the ramp unit.

1.4.4 Test conditions

- Testing is based on ICAO Annex 10, the relevant RTCA & EUROCAE MOPS (signals in space - reply capability - messages exchange protocols - test conditions).
- The transponders will be tested in real situation, that is, aboard stationary aircraft, preferably out of the hangar to avoid reflection.

1.5 SHORT HISTORIC

The ramp equipment for XPDR maintenance testing did evolve from the early tools, totally manual test sets only capable of fixed, Mode A/C interrogations (only the spacing P1 - P3 was variable), fixed PRF and SLS conditions, and few reply analyses (frequency, rough power, % of reply, pulse position of F2 only and acceptance window for other ones), up to the present generation in use, capable of measuring under variable interrogation parameters (pulses, SLS) most of the pulse characteristics (including frequency variations) with a higher accuracy.

The tendency is now to produce test tools digitally controlled (e.g. touch screen or remote control by PC through GICB links) but through long procedure, semi-automatic, and used mainly in lab. Most ramp tools in use are variants with capabilities reduced on both interrogations and replies, characteristic and display; part of the problem is linked to the time limits, to user technicity, to price.

Mode S is now included in these equipment, limited to electrical parameters and some protocols.

1.6 TRANSPONDER PERFORMANCE ANALYSERS

Starting in 1984, two successive mobile test installations have been built for measuring transponders either on the bench or aboard moving aircraft on airports : the MTPA first, and then the DATAS were built into a half-trailer with electrical power supply in order to have complete electrical autonomy; installed beside the main runway of European airports where they could measure the operational transponders of aircraft just before take-off or after landing and sometimes also on the main taxi-way.

Thousands of transponders have been measured and statistical data collected, served as support for ATC surveillance plannings. Information on the defective tranponders was also transmitted to administrations and companies, but the follow-up of this procedure was not really engaged.

During the same period, the equipment served as a very useful tool for transponder problem analysis and for development, investigations and pre-certification of the first European Mode S transponders.

Altough the technology and the use of these equipment were obsolete in 1995, it is a good basis for the present task.

1.7 PRESENT SITUATION

Table 1 : TOOL'S AVAILABILITY

	User	Object	Certification & operational validation	Maintenance	Investigations simulations
BENCH test unit	Test centres & administrations (+ JAA)	XPDR electric	existing (1) to upgrade	existing (1) to upgrade	existing (1) to upgrade
		ADLP electric	NOT existing	NOT existing	NOT existing
		XPDR protocols	NOT existing	NOT existing	specific bench
		ADLP protocols	NOT existing	NOT existing	
RAMP test unit	Test centres & aircraft operators	XPDR electric		existing (2) to upgrade	
		ADLP electric	NOT existing	NOT existing	NOT existing
		XPDR protocols, ADLP protocols	existing , to upgrade	existing (2) to upgrade	existing , to upgrade

NOTE 1	*some equipment can test most of the parameters wanted (see next chapter) on the bench, but operation is both long and semi-automatic.*
NOTE 2	*simple ramp test sets exist, but they test few parameters and their precision do not always follow the improved accuracy that is wanted in the future ATC environment.*

New ramp test sets are in preparation, that include automatic sequences; it is highly probable that their increased capabilities will join our present request, at least partially. The present document is then a way of standardising these tools, to reach the minimum commonality.

2 CURRENT LISTS OF TESTS

2.1 MODE A&C : POSSIBLE AND NECESSARY TESTS

2.1.1 GTVS Test lists (see ref 2 & 3)

Some years ago, a feasilbility study was submitted for an equipment called GTVS (Ground Transponder Verification System), to be installed on airports for measuring the transponders aboard the landing aircraft.

The required list of tests took into account

1 the results of 5 years of measurements with the MTPA, reporting in particular fault percentage

2 the theoretical consequences of malfunctions

3 the real consequences observed during combined MTPA campaigns (where MTPA result was linked to simultaneous radar observations)

4 the administrations reports (" Central Transponder File")

5 the possibility of automatic measuring and realistic field results.

Trials and theoretical works executed by the study contractors showed that a set of additional measurements could probably be executed in their GTVS proposal. However, "variable" opinions existed about the possibility to execute these tests on moving aircraft with valid and operational results.

These lists of tests are shown in Table 2.

For the BENCH or RAMP test sets we are dealing in this paper, the aircraft position is not a problem, and time is not limited, at least it is not a question of seconds. RAMP means here that the transponder is in a stationary aircraft (e.g. in, or better, out of its hangar).

Therefore, we may consider that the best solution would be to execute ALL the tests developed in Table 2 and to take care of the 5 considerations above.

2.1.2 STFTV priorities (see ref 4)

The Task Force for Transponder Verification issued in 1995-96 a report that developed considerations and propositions concerning the verification of transponder behaviour in the ATC surveillance environment.

Concerning parameter testing during lifetime, the following priorities were established:

- to test on RAMP every year the transponder, on the BENCH every 2 years;
- the RAMP tests should follow the FAR 43 regulations, in an " Europeanised" JAR version, that is, completed by F1 - F2 spacing
  Mode A and C accept *vs.* P1 & P3 spacing;
- the BENCH tests should follow all FAR 43 measurements with the addition of
  sidelobe suppression *vs.* P1 ⇒ P2 spacing
  reply delay time
  reply % at PRF 500
  Mode A and C acceptance *vs.* P1 & P3 width
  width of ALL pulses.

Additionally, after each passage on the bench, whatever its reason and periodicity, the characteristics had to be restored to the NOMINAL value. And transponders older than 12 years should pass every year a visit on the bench.

2.1.3 Recent FAA field study (see ref 5)

A recent field study of transponders aboard General Aviation aircraft in the USA was made using the modified FAA DATAS equipment ; made on 548 flying aircraft, the test covered 31 parameters (those executed by the EEC plus some additional ones).

The percentage of failures are significantly high if one considers the strict ICAO norms; but they refer to General Aviation and in particular to aircraft rarely flying IFR, so the figures will not be analysed. If we compare the relative importance of each parameter (linked, as in our studies, to the effect of a corresponding failure on ATC functionis) between this study and the other ones, one may point out:

- altitude errors (or failure to report it) and delay difference Mode A *vs.* C (not measured)
- sidelobe suppression *vs.* P1/P2 ratio and Mode A/C *vs.* P1 & P3 width, which were measured but showed errors only in old transponder series now out of use.

2.1.4 A first list of tests in Mode A/C

Rebuilding the lists of parameters to test mentioned in the above paragraphs, with more coherence, including all the tests executed during MTPA & DATAS campaigns and the recent FAA study, we get in Table 2 a first list for a Bench Test System, concerning Mode A/C only. (1)

It incudes two columns revealing the importance of the measured parameter (theoretical consequences of malfunctions), the occurence of faults during 1984 -1988 and 1991-1993 MTPA-DATAS campaigns and the duration of the test.

2.2 MODE S CHARACTERISTICS

The emergence of Mode S engaged the equipment manufacturers to develop Mode S transponder test sets some years ago; this generation of tools allows a series of electric characteristics to be tested., combined with a few essential protocol exchange verifications.

2.2.1 Ramp test set capabilities in all Modes

The possibilities of presently available ramp test sets are given in Table 3. Due to time limits and some other considerations (economy, technical difficulties and unawareness of some misbehaviour), the full amount of tests developed in Table 2 is not available or desirable on this sort of tool. (1)

2.2.2 RTCA & EUROCAE documents in Mode S / Intermode

RTCA MOPS DO-181A and EUROCAE MOPS ED-73 describe the Mode S transponder and the tests procedures to ensure the transponder is complying with the ICAO specifications (defined in the “Annex-10”); chapter 3 contains the minimum performance specifications, chapter 5 tests procedures to be executed in the laboratory, chapter 6 some additional ones executed on the ramp.

Altough not being a maintenance document, but a manufacturing verification / certification test description, it is used as a main source document for establishing maintenance procedures and rules.

The document being a mandatory reference for the definition of the characteristics, it will serve as such in the present paper; more, in order not to reinvent the wheel, we will use the protocol procedures directly as they are listed (and e.g. use their number sequence, procedures 1 to 37); these protocol procedures are shown in Table 4.

NOTE 1	*For the sake of comparison, a numbering common to all tables (including those in next chapter) has been used - this explains the “holes” in the number sequences - :* *n° 1 ⇒ 19 : electrical characteristics of the transponder's transmission (1090 Mhz)* *n° 21 ⇒ 39 : electrical characteristics, transponder's reception capability (1030 Mhz)* *no numbers for the message / protocol tests, as they will be regrouped with the MOPS procedure tests that follow.*

Table 2 : FIRST SERIES of MODE A/C TESTS

Transponder's transmission characteristics (1090 Mhz)	MTPA + DATAS mean failure occurence (%) 84-88 / 91-93	MTPA + DATAS impor-tance	GTVS impor-tance	FAA impor-tance	STFTV require-ments
1 - reply frequency	3.8 / 2.0	XXX	XXX	XX	F
2 - mean output power	4.6 / 1.9	XX	XX	XX	F
3 - pulse amplitude variation during a reply	-		XX	-	
4 - pulse positions : max offset . " " : mean offset	1.9 / 1.8	XX	XXX XXX	XXX	S
5 - pulse width (mean of all pulses)	4.7 / 1.8	XX	XX	XX	S_B
6 - Mode A code validity	- / (a)		XX	-	
7 - Mode C : altitude report . " " on the ground	- (a)		XX	XXX	F
8 - delay time, delay time jitter	3.0 / 0.8 -	X	XX	X	S_B
9 - delay time difference Mode A *vs.* Mode C	-			XXX	
10 - delay time *vs.* input level				-	
11 - squitter periodicity (no interrogations)	-		XXX	-	
12 - reply pulse rise & decay times	-		X	-	
13 - reply rate *vs.* PRF	-			-	
13 reduced form - reply rate @ 235 hz . @ 500 hz	- / 0.8	X	XX	-	F S
Receiver parameters (1030 Mhz)					
21 - MTL Mode A, Mode C . MTL difference Mode A *vs.* Mode C	- / (a) - / (a)	X -	XX -	X	F
22 - dead time	Å 0 / -		X	-	
23 - suppression time	0.7 / 0.6	X		X	
24 - receiving frequency acceptance	-		XXX	-	
25 - sidelobe suppression *vs.* P1 / P2 level ratio	0.8 / Å 0			XX	F (0 &9 dB)
26 - sidelobe suppression *vs.* P1 ⇒ P2 spacing	4.7 / 0.8 (b)	XX		XXX	S_B
27 - sidelobe suppression *vs.* P2 pulse width	Å 0 / -			-	
28 - interference (additional P1* - P1 - P3)	(a) / -				
29 - Mode A acceptance *vs.* P1 ⇒ P3 spacing . idem Mode C	0.6 / 2.3 1.4 / 2.1	XX XX	X X	X X	S S
30 - Mode A&C acceptance *vs.* P1 & P3 width	0.3 / 16.3 (c)			X	S_B

LEGEND

- *-* *not measured*
- *a* *few measurements only; not statistically significative*
- *b* *one old series of transponder showed some strange behaviour*
- *c* *one or two old series of transponder reacted to very short P1&P3 pulses (< 200 ns)*
- *X, XX, XXX* *by increasing importance*
- *F* *FAR 43 mandatory biennal Ramp test ; included in STFTV*
- *S* *STFTV addition to the FAR 43 rrequirements, for Ramp testing*
- S_B *STFTV supplementary addition for Bench testing.*

Table 3 : PRESENT RAMP TESTER CAPABILITIES

Transmission parameters (1090 Mhz)	Mode A/C	Intermodes	Mode S
1 - reply frequency	Y	Y	Y
2 - mean output power	Y	Y	Y
4 - pulse positions : mean offset	Y		
5 - pulse width (mean of all pulses)	Y		
8 - delay time , delay time jitter	Y	Y	Y
11 - squitter periodicity	n a	na	Y
15 - diversity isolation	n a		Y
Receiver parameters (1030 Mhz)			
21 - MTL all Mode s	Y	Y	Y
25 - sidelobe suppression *vs.* P1 / P2 level ratio	Y	Y	
. (in Mode S : " " *vs.* P5 / P6 level ratio	n a	n a	/
31 reduced - Intermode A&C Only All-Call	n a	Y	(Y) *(1)*
32 - Intermodes acceptance	n a	n a	
. *vs.* P3 ⇒ P4 spacing			
33 - Mode S acceptance	n a	n a	(Y)
. *vs.* P2 ⇒ SyncPh.Rev. spacing			On / Off only
Messages control Up / Down			
- uplink address control			Y
- long squitter			Y
- UF 4			Y
- UF 5			Y
- UF 11 / Mode S Only All-Call	n a	n a	Y
- UF 16			Y
- UF 20			Y
- UF 21			Y
- Comm - A			limited *(2)*
- Comm - B			limited *(2)*
- Comm - C			
- Comm - D			

LEGEND

Y yes, available

n a *not applicable to this Mode*

(1) should not reply

(2) in octal; Comm-A only MA field programmable, limited and uneasy, Comm-B difficult to extract the GICB registers (BDS) .

Table 4 : MOPS ED-73 , PROTOCOL PROCEDURES

Procedures	MOPS number	XPDR level	Laboratory tests	Ramp tests
error protection	1	ALL	Y	Y
interrogation acceptance	2	ALL	Y	Y
CA verification	(3 : in 2)	ALL	Y	Y
non-selective lockout	4	ALL	Y	
selective lockout	5	ALL	Y	
squitter verification	6	ALL	Y	Y
FS & VS protocol / code	7	ALL	Y	
PI verification (in all tests >	(8 : in 2)	ALL	Y	Y
address verification	9	ALL	Y	Y
altitude report	10	ALL	Y	Y
4096 code	11	ALL	Y	Y
RI, acquisition & maximum airspeed	12	ALL	Y	Y
PR reply probability / stochastic acquisition	13	ALL	Y	Y
Comm-A interface & information contents	15	2	Y	
broadcast All-Call formats (uplink)	16	2	Y	
downlink interface DF 0, DF 16	(17 : in 18)	2	Y	Y
Comm-B protocol	18	2	Y	Y
AIS flight ident protocol & interface	19	2	Y	
basic / extended capability report	20	2	Y	
directed Comm-B	21	2	Y	
Comm-B broadcast	21A	2	Y	
downlink interface, storage design, buffer rate	22	2	Y	
downlink interface, no-storage design	23	2	Y	
Comm-C protocol	24	3	Y	Y
uplink interface, ELM Comm-C	25	3	Y	
Comm-D protocol	26	4	Y	Y
directed Comm-D	27	4	Y	
Comm-D interface	28	4	Y	
Comm-U uplink interface	29	2	Y	
sensitivity level operation	30	ACAS	Y	Y
RA report to Mode S ground interrogator	31	ACAS	Y	
transmission of ACAS capability information	32	ACAS	Y	
coordination	33	ACAS	Y	Y
ACAS broadcast message	34	ACAS	Y	
XPDR replies to incoming ACAS R messages	35	ACAS	Y	
XPDR / ACAS throughput	36	ACAS	Y	
XPDR communication timing	37	ACAS	Y	

Numbers in brackets means the parameter can be tested during another procedure; this reduces the total measurement time .

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3 PROPOSED TESTS LIST

3.1 GLOBAL PROPOSAL

To develop new ramp & lab test benches, one has to consider the following points:

- the tests tool will have two variants, one used in the laboratory, one operated on the ramp;
- the ramp tool shall be a "reduced" version of the lab tool, for both economical reason and homogeneity of the measurements;
- the lab tool shall be able to test ALL the parameters defined in ICAO Annex 10 document as well as in the various MOPS mentioned above (concerning transponders);
- the ramp tool shall be able to test all the IMPORTANT parameters, based on the earlier tools; and studies, as shown in the above chapter; JAA43, STFTV and MOPS protocols list contains obligations for ramp testing, but we feel this is far from being enough;
- in order to preserve the future, the tools will be able to enlarge their capabilities, at least in the protocol domain;
- the ramp tool will be built first (see § 1.4.3).

3.2 LATEST REQUIREMENTS

In order to support the Enhanced Surveillance program (see POEMS), the ramp tool must,

analyse long squitters,

extract & display in clear all parameters contained in the GICB registers as defined in the Mode S Specific Service Manual,

(extract & display in clear AICB messages);

the lab tool must, in addition

test all protocols for DATA LINK,

be able to vary the interrogator's frequency.

3.3 LIST OF TESTS AND PROCEDURES

3.3.1 List structure

The following Tables 5 & 6 are built by combining all tests in Tables 2, 3 & 4 above, plus the equivalent tests in other Modes whenever it applies.

A subset of this “maximum” list is then proposed for the Laboratory test set; a further reduced list is then eventually proposed for the Ramp test set.

Each procedure will describe a set of n [interrogation --> reply] sequences, that must be carried out to verify each characteristic or action of the transponder. For the electric tests, it corresponds to n identical sequences, where n is a function of the required accuracy. For the protocol tests, it is a series of necessary transactions.

3.3.2 Procedures

Up to now, each test sequence was devoted to one characteristic or action; but it is possible to group several parameter measurements in one reply (or on the mean of n replies, see above) to gain time. It is especially useful for the Ramp test set. So, the “new” procedures proposed in this paper will combine several measurements automatically. The way choosen for this grouping allows separation between the tests compulsorily executed by the ramp test sets and those done in the laboratory or workshop. A grouping that is not mandatory, just a proposed improvement.

3.3.3 Tests in different Modes

The way the characteristic is measured in Mode A&C or Intermode or Mode S may differ not only in the interrogations patterns and reply data, but also in the importance for ATC or by the fact that the parameter measured under one Mode is already verified in another.

This is to explain that

- some tests are present in Mode A and/or in Mode S and not in Intermode,
- the propositions for ramp testing differ,
- the regrouping of tests in procedures differs between Mode A&C, Intemodes and Mode S,
- electric tests generally use Mode or Intermode A, except in sets P 53, 58, 66, 67, 77, 85, 86 & 87, where both Modes or Intermodes A and C interrogations are generated.

Mode A/C transponders only need to be verified by tests in the first tests / procedures dual column; the Mode S types are to be checked versus all tests / procedures.

3.4 SUGGESTED LIST OF PROCEDURES FOR THE RAMP TEST SET

3.4.1 Preamble

The fact that a test or a procedure is proposed for the ramp test set does not automatically make it mandatory for Maintenance rules; these last are defined by other regulation bodies (JAR or others). The test sets here defined must at least be able to execute the present ramp imposed tests plus those recently proposed (see above chapters).

Besides, it must be recalled here that the ramp test set objective is not to replace the ramp part of the certification of a transponder type. Neither to replace the -long- test procedure defined in the Eurocae MOPS to verify the the transponders performance. But some of their measurement principle (MOPS §5.4) are reproduced or used as a basis.

3.4.2 Presentation

Some of the tests listed in the Tables 5 and 6 are already executed on the present generation of ramp test sets. Naturally they include, at least, all what is mandatory in FAR43 for Mode A&C.

The objective is to enlarge the capacity of these equipment to

- all tests proposed to be mandatory on ramp, in the STFTV report,
- similar tests in Mode S / Intermodes A&C, whenever it applies,
- some tests considered as important (see § 2.1) and generally already executable on lab test sets and/or suggested for bench testing in the STFTV report (see § 2.1.2),
- protocol tests necessary for long squitter and GICB register extraction, as recently required.

The following keys are used in the Tables 5 and 6 (shown at end of this chapter 3) :

in italics	test presently available on most ramp test sets
with dual border	test mandatory on ramp by present rules, plus those in the STFTV recommendations plus those similar in Mode S & Intermode
with bold border	to be executed in lab but which are also proposed for the ramp test sets, being considered as important for ATC (see 2.1.1)
in bold oblique	the procedures proposed for ramp test sets

The numbering scheme is the following:

electric tests are numbered
A1... for Modes A&C, T1... for Intermodes, S1... for Mode S (TS1... when combined)
(see also note on bottom of page 6)
protocol tests are listed 1... 3x, as in Table 4 & as in the MOPS.
The procedures are listed P1 ... P89 (starting with the protocol ones to keep the same numbers as in the MOPS document).

3.4.3 The tests choosen for the Ramp tool

3.4.3.1 *Modes A&C parameters*

In addition to present equipment's capability, one adds the tests

pulse amplitude variation,
delay time difference Mode A *vs.* Mode C,
Mode A code validity, Mode C height validity (on the ground value),
reply rate at various PRF instead of only 235 or 500 hz,
Mode A & C acceptance *vs.* P1 ⇒ P3 spacing;

all these tests that can be easily implemented, if not already executed in some ramp equipment.

Remark : test A4 is presently limited to the F2 position; the offset of ALL pulses should be verified and the maximum value (in fact, the worst) displayed.

3.4.3.2 *Intermodes A&C parameters*

The Intermode A&C acceptance *vs.* P4 short or long pulse (test *T31red)* is enlarged to a complete test T31, the acceptance *vs.* P4 width.

Important also is the test T32, Intermode A&C acceptance *vs.* P3 ⇒ P4 spacing.

3.4.3.3 *Mode S - electric parameters*

Are added to the present test sets possibilities:

pulse positions (mean offset is enough here),
pulse amplitude variation from the 1st to the 56^{th} or 112^{th},
mean pulse width,
mixed reply rate capability (a complex series of various interrogations at various rates),
Mode S acceptance *vs.* P1 ⇒ Sync. Phase Reversal spacing.

All these tests are important for a correct decoding (a 112-bit long message is much more sensitive to a deviating clock than a 12-bit in the Mode A reply); including the Sync Phase Reversal, where the acceptance of the P2 - P6 spacing should be verified inside a large window and not just limited to YES or NO at nominal time.

Besides, the squitter verification in Mode S is transfered to the protocol procedures list (see next paragraph), because the squitter generation in recent transponders (e.g. Mark 4 types) is a complex combination of short and long squitters whose contents vary in accordance to GICB / Mode S Specific Service Manual.

Finally, altough desirable, it is not possible to test on the ramp (that is, without cable connections) the diversity parameters, the two antennas receiving simultaneously the signals, albeit with very small time delay and power difference.

3.4.3.4 *Mode S protocols*

The test procedure n° 1 (“P1”), Error Protection, is not possible with a XPDR installed in an aircraft, the address being “cabled” in the rack. Only the correct address will be verified as part of any other tests.

Test procedure n° 3, the capability, and procedure n° 8, the PI verification, are checked in the replies DF11 in procedure P 2.

Squitter verification protocol n° 6 : the squitter protocols have changed since their increasing use in ADS; simple and extended squitter are now part of the proposed and/or mandatory elements of the future Mode S transponders. Therefore, in order to saveguard the future, the test bench shall be built such as to accept and analyse the various squitter contents and periodicity (P 6).

Mode S addresses are tested in various combinations to discover e.g. incorrect cabling or bad contact in the transponder rack mounting (procedure P 9.).

Procedure 10 verifies the altitude reports, but this depends on the installation possibilities.

Procedure 11 corresponds to the Mode A code validity executed on Mode A&C transponders, but contained here in a Mode S downlink messages; the importance is therefore the same.

Maximum airspeed and identification(flight plan or a/c registration) of the aircraft are useful data to the air traffic controller; stochastic behaviour of the transponder appears as important for a smooth radar behaviour; those two characteristics are easily tested in procedures 12, 19 & 13.

Comm B messages are important in the data link exchanges between ground and aircraft, for various reasons, including ADS; but they are not mandatory for all versions / levels of these transponders; more, some characteristics are not yet adopted neither definitive. But many BDS (see Mode S Specific Services) are already defined. Therefore, following the latest requests (see § 3.2) both a new procedure P 17 concerning the GICB registers and the easily applicable procedure P 20 will be kept for ramp testing,

3.4.4 Proposed List of Procedures

Finally, the following list of procedures is proposed for the Ramp Test set :

Mode A&C	:	procedures P 51, 52, 53, 57, 58, 62 & 66 .
Mode S and Intermode A&C	:	procedures P 71, 72, 75, 77, 78, 86, 87 & 88 .
Mode S Protocol	:	procedures P 2, 6, 9, 10, 11, 12, 13, 17, 19 & 20.

3.5 LIST OF PROCEDURES FOR THE LABORATORY TEST SET

This version of the test set is of course much more complete as well as more flexible, because different types of users are interested.

Research and developments : the operator may want to tests many problems encountered in various now unkmown situations, etc...

Therefore, no limitations should be applied to the test lists and all the procedures developed in the Tables 5 & 6 should be available to the technician.

Table 5 : MAXIMUM TEST LIST - ELECTRIC PARAMETERS

Transponder's transmission characteristics (1090 Mhz)	All XPDRs Mode A/C interrogations		Mode S XPDRs only Intermode interrogations		Mode S interrogations	
	test	procedure	test	procedure	test	procedure
1 - reply frequency	*A1*	***P 51***	*TS1*			***P 71***
2 - mean output power	*A2*	***P 52***	*TS2*			***P 72***
3 - pulse amplitude variation during a reply	A3		TS3			
4 - pulse positions : max & mean offset	*A4*		TS4			
5 - pulse width (mean of all pulses)	*A5*		TS5			
6 - Mode A code validity	A6		*see P11*			
7 - Mode C : altitude	A7	***P 53***	*see P10*			
8 - delay time, delay time jitter	A8		TS8			P 73
9 - delay time difference Mode A *vs.* Mode C	A9					
10 - delay time *vs.* input level	A10	P 54				
11 - squitter / unsolicited replies	A11	P 55			*see P 6*	
12 - reply pulse rise & decay times	A12	P 56			S12	P 74
13 - reply rate vs. PRF	A13	***P 57***				
13 reduced : reply rate @ 500 hz	*A13 r*					
14 - mixed reply rate capability Mode A + S					S14	***P 75***
15 - diversity isolation					*S15*	P 76
Receiver capabilities (1030 Mhz)						
21 - receiver dynamic range (>MTLs) all modes	*A21*	***P 58***	*T21*	***P 77***	*S21*	***P 78***
22 - dead time	A22	P 59	T22	*and*	S22	P 79
23 - suppression time	A23	P 60			S23	P 80
24 - receiving frequency acceptance	A24	P 61			S24	P 81
25 - sidelobe suppression *vs.* P1 / P2 level ratio . (in Mode S : *vs.* P5 / P6 level ratio)	*A25*	***P 62***			S25	P 82
26 - sidelobe suppression *vs.* P1 ⇒ P2 spacing	A26	P 63	T26	P 83		
27 - sidelobe suppression *vs.* P2 pulse width	A27	P 64				
28 - interference	A28	P 65			S28	P 84
29 - Mode A&C accep. *vs.* P1 ⇒ P3 spacing . (for Mode S XPDR : in Intermode A&C)	*A29*	***P 66***	T29	P 85		
30- Mode A&C acceptance *vs.* P1 & P3 width	A30	P 67				
31 - Intermode A&C acceptance *vs.* P4 width			T31	***P 86***		
. *31 reduced* : Intermode A&C only All-Call			*T31 r*			
32 - Intermode A&C accep. *vs.* P3 ⇒ P4 spacing			T32	***P 87***		
33 - Mode S accept. *vs.* P2 ⇒ SyPh Rev spacing					*S33*	***P 88***

see page 10 (§ 3 4.2) for presentation keys

Table 6 : MAXIMUM TEST LIST - PROTOCOLS

Procedures	MOPS number	UF	DF	proce-dures
error protection	1	04, 20	05, 21	P 1
interrogation acceptance	2	many (+IM)	many	P 2
CA verification (use instead : test P 2 >	(3)			
non-selective lockout	4	many (+IM)	many	P 4
selective lockout	5	04,05, 11, 20, 21	....	P 5
squitter verification	6 mod	/	11, 17	P 6
FS & VS protocol / code	7	04, 05, 0	04	P 7
PI verification (use tests P 4 & P 5 >	(8)	/	/	
address verification	9	04, 05, 11	04, 05, 11	P 9
altitude report	10	04 (+IM)	04, 20	P 10
4096 code (code set)	11	05	05, 21	P 11
RI, acquisition & maximum airspeed	12	00, 16	00, 16	P 12
PR reply probability / stochastic acquisition	13	11	11	P 13
Comm-A interface & information contents	15	20, 21		P 15
broadcast All-Call formats (uplink)	16	00, 04, 05, 11		P 16
downlink interface (use instead : test P 18>	(17)		00, 16	
GICB register extraction	-	04,	20	P 17
Comm-B protocol	18	04, 05, 20, 21	04, 20, 21	P 18
AIS flight ident protocol & interface	19	04, 05	20, 21	P 19
basic / extended capability report	20	04	20	P 20
directed Comm-B	21			
Comm-B broadcast	21A	04, 05, 20, 21	04, 05, 20, 21	P 21
downlink interface, storage design, buffer rate	22			P 22
downlink interface, no-storage design	23			P 23
Comm-C protocol	24			P 24
uplink interface, ELM Comm-C	25	04, 05, 20,	04, 05, 20,	P 25
Comm-D protocol	26	21, 24	21, 24	P 26
directed Comm-D	27			P 27
Comm-D interface	28			P 28
Comm-U uplink interface	29	00, 16		P 29
sensitivity level operation	30			P 30
RA report to Mode S ground interrogator	31			P 31
transmission of ACAS capability information	32	see ACAS		P 32
coordination	33			P 33
ACAS broadcast message	34			P 34
XPDR replies to incoming ACAS R messages	35			P 35
XPDR / ACAS throughput	36			P 36
XPDR communication timing	37			P 37

Note | *IM = Intermode interrogations in addition to the UF s*

see page 10 (§ 3 4.2) for presentation keys

4 RAMP TEST SET

4.1 PROCEDURES ANALYSIS

4.1.1 Legend

1 - MS = Eurocae MOPS for SSR transponders : performance specifications (§ 3.2 ...)

2 - MT = " " " " " : test procedures data (§ 5.4)

3 - Mean: in the 3 paragraphs 4.1.1 to 4.1.3, all values are computed as the mean of 100 replies (100 identical [interrogation--reply] sequences)

4 - Time spacings are counted from the pulses front edge at half-amplitude

5 - Here, on ramp: . . when maximum load is requested, Mode A code is set to 7377 (+ the SPI if necessary) because the highest load code A 7777 could mislead safety on radars in the vicinity;

. . when a variation between successive bits is desirable, A 1642 is used.

6 - Unless otherwise stated, PRF is 450 hz for Mode A&C and 50 hz for Intermodes and Mode S

7 - The sign ‡ means in a sequence : the interrogation followed by its reply.

8 - The sign ☞ shows settings on the transponder side (fixed and / or modified during the test) entered / executed by the " pilot ".

4.1.2 Mode A&C Procedures

Procedure *P 51*

a *Verification*

Reply Frequency.

b *Performance specifications*

MS 3.3.1 - MT 5.4.2.1.

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm; Mode A.

☞ XPDR code : A 7377 + SPI.

d *Test progress*

100 [interrogation ‡ reply] sequences.

e *Measurement & display*

frequency (1090 Mhz): mean value of all pulses.

Procedure *P 52*

a *Verification*

Mean Output Power, Pulse Amplitude Variation, Mean Pulse Width, Pulse Positions,
Mode A pulse decoding.

b *Performance specifications*

MS 3.3.3, 3.5.1, 2, 4, 5 & 6 - MT 5.4.2.2 , 5.4.3.1 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm; Mode A.

d *Test progress*

100 [interrogation ‡ reply] sequences with ☞ XPDR set to code A 7377
repeated with successively ☞ codes A 4000 and A 0400.

e *Measurement & display*

Reply code displayed;
for each code:
power : . . . . . mean value of all pulses / mean value of lowest pulse
maximum variation between all pulse in a reply (min-max).
position of ALL pulses (*vs.* F1 + n x 1.45 µs) : mean value of each pulse
and the maximum offset (that is, the offset of the “worst” pulse)
pulse width : . . mean value of all pulses.

Procedure *P 53*

a *Verification*

Delay Time, Delay Time Jitter, Delay Time Difference Mode A *vs.* C, Code C .

b *Performance specifications*

MS 3.7.1 , Annex 10 (Gilham conversion) - MT 5.4.3.3 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm .

d *Test progress*

100 [interrogation ‡ reply] sequences in Mode A; idem Mode C
☞ XPDR code A 1642, altimeter switched out if possible;
(if not : the altimeter will correspond to the “ground altitude”).

e *Measurement & display*

Delay time (P3 ⇒ F1) : mean value Mode A and Mode C are compared ;
jitter on delay time (σ of 100 replies);
reply altitude decoded (either C 0000 or xxxx, corresponding to -1000 ft or to “ground altitude”).

Procedure ***P 57***

a *Verification*

Reply Rate *vs.* PRF.

b *Performance specifications*

MS 3.4.1 - MT 5.4.2.5 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm

☞ XPDR code : A 7377 + SPI .

d *Test progress*

PRF 500 interrogations per sec during one sec, followed by 5 or 10 sec rest,
then idem at 600, 700, . . . 1500 interrogations per sec.

e *Measurement & display*

Diagram : reply % *vs.* PRF.

Procedure ***P 58***

a *Verification*

Mode A & C Sensitivity (MTL).

b *Performance specifications*

MS 3.2.4 - MT 5.4.1.2 .

c *Fixed settings*

Interrogator at nominal setting;

☞ XPDR code : A 1642, altimeter at zero if possible;
(if not : the altimeter will correspond to the “ground altitude”).

d *Test progress*

100 [interrogation ‡ reply] sequences, level at XPDR input : -60 ⇒ -80 dBm, per 1 dB steps
first with Mode A, then repeated using Mode C.

e *Measurement & display*

Diagram : reply % *vs.* input power; MTL = interrogator’s level when reply rate crosses 90 %
MTL difference Mode A ⇔ C displayed.

Procedure *P 62*

a *Verification*

Sidelobe Suppression *vs.* P1 / P2 Level Ratio.

b *Performance specifications*

MS 3.8.2 - MT 5.4.4.2 .

c *Fixed settings*

Interrogator at nominal setting;

☞ XPDR code : A 1642, altimeter at zero if possible;

(if not : the altimeter will correspond to the “ground altitude”).

d *Test progress*

With a P2 at nominal position & width, P2/ P1 ratio varying from -12 ⇒ + 3 dB, per 1 dB steps

100 [interrogation ‡ reply] sequences for each step

repeated for the level at XPDR input : -50 dBm & MTL + 3 dB.

e *Measurement & display*

Diagrams : reply % *vs.* P2 / P1 ratio, tolerance areas shown (for the 2 input power levels).

Reduced version (if available time is too short) : replace the diagrams by the reply % at -9 dB and 0 dB only.

Procedure *P 66*

a *Verification*

Mode A & C Acceptance *vs.* P1 ⇒ P3 Spacing.

b *Performance specifications*

MS 3.9.3 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal setting; no P2; level at XPDR input : MTL +10 dB

☞ XPDR code : A 1642.

d *Test progress*

P1 ⇒ P3 spacing varying from 6.5 ⇒ 9.5 µs and 19.5 ⇒ 22.5 µs, per 25 ns steps

100 [interrogation ‡ reply] sequences for each step.

e *Measurement & display*

Diagrams : reply % *vs.* P1 ⇒ P3 spacing, tolerance areas shown

for both Mode A (6 ⇒ 10 µs) and Mode C (19 ⇒ 23 µs).

Reduced version (if available time is too short) : replace the diagrams by a set of values;

reply % at -7.0, 7.8, 8.2, 9.0 µs and 20.0, 20.8, 21.2, 22.0 µs only.

4.1.3 Modes S electrical and Intermode A&C Procedures

Procedure *P 71*

a *Verification*

Reply Frequency.

b *Performance specifications*

MS 3.3.1 - MT 5.4.2.1 .

c *Fixed settings*

Interrogator at nominal setting; PRF 50 hz; level at XPDR input : -50 dBm

☞ XPDR code : A 1642.

d *Test progress*

100 [interrogation UF 05 ‡ reply DF 05] sequences

or [Intermode A ‡ reply DF11] sequences.

e *Measurement & display*

Frequency (1090 Mhz) : mean value of all Mode S pulses.

Procedure *P 72*

a *Verification*

Mean Output Power, Pulse Amplitude Variation, Mean Pulse Positions, Mean Pulse Width.

b *Performance specifications*

MS 3.3.3, 3.6.1 ⇒ 3.6.6 - MT 5.4.2.2, 5.4.3.2 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm

☞ XPDR code : A 1642.

d *Test progress*

100 [interrogation UF 05 or 21* ‡ reply DF 05 or 21*] sequences

or [Intermode A ‡ reply DF11] sequences.

e *Measurement & display*

Power : . . . . . mean value of all Mode S pulses

+ diagram : amplitude of each reply data pulse (1st ⇒ 56th or 112th *)

pulse position : mean offset (nominal *vs.* 1st pulse + (0.5 x n) µs)

pulse width: . . .mean value of, separately, the preamble pulses, the 0.5 µs pulses & the 1 µs pulses

*note * : depending on the capability of the XPDR.*

Procedure *P 75*

a *Verification*

Mixed Reply Rate Capability.

b *Performance specifications*

MS 3.4.2 - MT 5.4.2.5 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm

☞ XPDR code : A 7377 +SPI .

d *Test progress*

4 separated sequences lasting 1 sec each :

a - 500 interrogations Mode A uniformily mixed with 50 UF 05 interrogations * in 1 s

b - 120 interrogations Mode A uniformily mixed with 18 UF 05 interrogations * in 0.1 s, followed by 0.9 s rest

c - 30 interrogations Mode A uniformily mixed with 8 UF 05 interrogations * in 0.025 s, followed by 0.975 s rest

d - 2 interrogations Mode A uniformily mixed with 4 UF 05 interrogations * in 0.0016 s, followed by 0.9984 s rest .

note * : if the XPDR is equiped for long replies, respectively 16 of the 50, 6 of the 18, 4 of the 8 and 2 of the 4 interrogations must require long replies.

e *Measurement & display*

The XPDR must reply to ALL these interrogations.

Procedure *P 77*

a *Verification*

Intermode A & C Sensitivity (MTL).

b *Performance specifications*

MS 3.2.4 - MT 5.4.1.2 .

c *Fixed settings*

Interrogator at nominal setting;

☞ XPDR code : A 1642, altimeter at zero if possible;

(if not : the altimeter will correspond to the “ground altitude”).

d *Test progress*

100 [interrogation Intermode A ‡ reply DF11] sequences,

level at XPDR input : -60 ⇒ -80 dBm, 1 dB steps;

this repeated for Intermode C.

e *Measurement & display*

Diagrams : reply % *vs.* input power; MTL = interrogator’s level when reply rate crosses 90 %.

MTL difference Intermode A ⇔ C displayed.

Procedure ***P 78***

a *Verification*

Mode S Sensitivity (MTL).

b *Performance specifications*

MS 3.2.4 - MT 5.4.11 .

c *Fixed settings*

Interrogator at nominal setting;

☞ XPDR code : A 1642.

d *Test progress*

100 [interrogation UF 11 (with PR = 0) ‡ reply DF 11] sequences,

level at XPDR input : -60 ⇒ -80 dBm, per 1 dB steps.

e *Measurement & display*

Diagrams : reply % *vs.* input power; MTL = interrogator's level when reply rate crosses 90 %
(for MTL + 3 dB and higher, the reply rate must be 99 %).

Procedure ***P 86***

a *Verification*

Intermode A & C Acceptance vs. P4 Width.

b *Performance specifications*

MS 3.9.4 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal setting; no P2;

☞ XPDR code : A 1642, altimeter at zero if possible;

(if not : the altimeter will correspond to the "ground altitude").

d *Test progress*

Level at XPDR input : -21, -40 & -60 dBm

P4 varying from 1.0 ⇒ 3.0 µs, per 25 ns steps

100 [interrogation ‡ reply] sequences for each step & each input level.

e *Measurement & display*

Diagrams : reply % *vs.* P4 width, tolerance areas shown
for both Intermode A & C and for each of the 3 input levels.

Procedure *P 87*

a *Verification*

Intermode A & C Acceptance *vs.* P3 ⇒ P4 Spacing.

b *Performance specifications*

MS 3.9.3 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal setting; no P2;

☞ XPDR code : A 1642, altimeter at zero if possible;

(if not : the altimeter will correspond to the “ground altitude”).

d *Test progress*

Level at XPDR input : -21, -40 & -60 dBm

P3 ⇒ P4 spacing varying from 1.4 ⇒ 2.7 µs, per 25 ns steps

100 [interrogation ‡ reply] sequences for each step & each input level.

e *Measurement & display*

Diagrams : reply % *vs.* P3 ⇒ P4 spacing, tolerance areas shown for both Intermode A & C and for each of the 3 input levels.

Procedure *P 88*

a *Verification*

Mode S Acceptance *vs.* P2 ⇒ P6 (Sync. Phase Reversal) Spacing.

b *Performance specifications*

MS 1.6.5, 3.9.5 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal setting;

☞ XPDR code : A 1642.

d *Test progress*

P2 ⇒ Sy. Ph. Rev. spacing varying from 2.4 ⇒ 3.1 µs, per 25 ns steps;

level at XPDR input : MTL +3 dB and -50 dBm

100 [interrogation ‡ reply] sequences for each step for each power level.

e *Measurement & display*

Diagrams : reply % *vs.* P2 ⇒ Sync. Phase Reversal spacing, tolerance areas shown, both level curves shown.

4.1.4 Mode S Protocol Procedures

For all these protocol tests, the interrogator is at nominal regarding “electric” values; no pulse P2 is used; level at XPDR input is -50 dBm; uplink address is the XPDR address; XPDR code is A 7377.

Unless especially mentioned.

Some test are only applicable to some types of XPDRs, depending on their level or whether they are “Mark 4 “ or not (see the double asterisks **).

Diversity operation must be inhibited to avoid unequal, unknown reception by the XPDR and “jumping” problems : the power and delay differ, and, worse, the upper antenna may be totally invisible to the test set located on the ground; or simplier, the test set ignores which antenna is replying. Therefore, the top channel must be terminated by its characrteristic impedance.

Successive signs ‡ mean a sequence containing more than 1 interrogation followed by 1 reply.

ATTENTION : the Mode S Specific Services as well as the squitter protocol may still change in the near future; so, in some of the protocol tests (see : “ ATTENTION : THE SPECIFICATIONS MAY VARY”), the BDS definition, use, sequences, and repetition rate (if applicable) may be different from what is developed; but the princip of the measurement remains. Always refer to the latest version of th Mode S Specific Services (ref. 6) and Mode S Subnetwork SARPS.

The formats used in these tests are the following :

Uplink Formats :

UF 00	000	RL :1	0000	AQ : 1	00 0000 0000 0000 0000	**AP : 24**

UF 04	PC : 3	RR : 5	DI : 3	SD : 16	**AP : 24**
UF 05	PC : 3	RR : 5	DI : 3	SD : 16	**AP : 24**

UF 11	PR : 4	II: 4	000 0000 0000 0000 0000	**AP : 24**

UF 16	000	RL :1	0000	AQ : 1	00 0000 0000 0000 0000	MU : 56	**AP : 24**

UF 20	PC : 3	RR : 5	DI : 3	SD : 16	MA : 56	**AP : 24**
UF 21	PC : 3	RR : 5	DI : 3	SD : 16	MA : 56	**AP : 24**

11	RC : 2	NC : 4	MC : 80	**AP : 24**

(YY : x means x bits are devoted to this field YY ; *0000* show a series of zeros between fields)

Downlink Formats :

DF 00	VS : 1	00	SL : 3	00	RI : 4	00	AC : 13	**AP : 24**		
DF 04	FS : 3	DR : 5	UM : 6	AC : 13	**AP : 24**					
DF 05	FS : 3	DR : 5	UM : 6	ID : 13	**AP : 24**					
DF 11	PR : 4	**AA : 24**	PI : 24							
DF 16	VS : 1	00	SL :3	00	RI: 4	00	AC : 13	MV 56	**AP : 24**	
DF 17	FS : 3	DR : 5	DI : 3	SD : 16	MB : 56	**AP : 24**				
DF 20	FS : 3	DR : 5	UM: 6	AC : 13	MB : 56	**AP : 24**				
DF 21	FS : 3	DR : 5	UM: 6	ID : 13	MB : 56	**AP : 24**				
11	0	KE : 1	ND : 4	MD : 80	**AP : 24**					

(YY : x means x bits are devoted to this field YY ; *0000* show a series of zeros between fields)

Procedure ***P 2***

a *Verification*

Interrogation Acceptance.

b *Performance specifications*

MS 3.20.2.2 & 3, 3.21.1.1 & 4 , 3.23 - MT 5.4.13.4 / protocol procedure n° 2 .

c *Interrogation ‡ reply sequences*

- Without P2 : Mode A, C; Intermodes A/S, C/S, A Only, C Only
- with P2 (P2 level = P1) pulse included : the same ones
- Mode S: UF 0 { with RL = 0, =1 }
  UF 11 { PR, II = 0 } { address = FF FFFF hex }
  UF 4, 5, { with RR = 0, 15, 16, 17, 18, & 19 } { PC, DI, SD = 0 }
  UF 20, 21 { with RR = 0, 15, 16, 17, 18, & 19 } { PC, DI, SD, MA = 0 } (**)
  UF 16 { with RL = 0, =1 } (**)
  UF 24 { with RC = 2 } (**)

d *Control*

The correct reply in each of the Modes.

Procedure *P 6*

a *Verification*

Squitter / Extended Squitter.

b *Performance specifications*

MS 3.20.2.6 modified - MT 5.4.13.4 / protocol procedure n° 6 (already modified).

ATTENTION : THE SPECIFICATIONS MAY VARY :

GICB sequences and repetition rate are not definitive and the AIRBORNE / GROUND status may not be varied as desired.

c *Interrogation ǂ reply sequences*

Unsollicited replies in Mode S - There are no interrogations

To obtain valuable result in terms of periodicity, at least 400 different unsollicited replies must be observed for each of the following cases:

1 - XPDRs with *SHORT SQUITTER ONLY* : the short squitters

DF 11 are transmitted at an average rate of 1/sec,

contents : { CA = ..., II = 0 , PI = address in clear}

2 - XPDRs with *EXTENDED SQUITTER* : a (not controlled) mixture of short & long squitters :

DF 11 like above

DF 17 : [FS = 1] [DR = 0] [DI = 7] [SD = 0x00] [MB = z] [PI = XPDRs address]

where x is the subfield BDS2 and equals 5, 6, 7, or 8

corresponding to GICB registers 0,5 ; 0,6 ; 0,7 or 0,8)

where z = 56 bits of data defined in the Mode S Specific Service Manual

average rate of 2/sec down to 1/10 sec, depending on the register and the aircraft movement, with a Surface Position Squitter that may vary if so determined by register 0,7 Squitter Status.

☞ For some registers, the transponder must be set to fictitious AIRBORNE status; it is not sure whether this is possible on all aircraft; see the remark above.

d *Control*

The correct contents of DF 11 and DF 17;

the random transmission rate : a diagram Number of events *vs.* time (in ms) between messages for the following registers (the list is valid today and may vary) :

DF 11	at a rate of	1 / sec (limits : 0.8 to 1.2 s)
register 0,5		2 / sec (limits : 0.4 to 0.6 s) aircraft being set “AIRBORNE”
register 0,6		1 / 5 s (limits : 4.8 to 5.2 s) aircraft NOT set “AIRBORNE”
register 0,7		?
register 0,8		1 / 5 s (limits : 4.8 to 5.2 s) if aircraft is set “AIRBORNE”
		1 / 10 s (limits : 9.6 to 10.4 s) if aircraft is left stationnery.

Procedure *P 9*

a *Verification*

Mode S Address.

b *Performance specifications*

MS 3.17.1, 3.20.2.1, 2 &11 - MT 5.4.13.4 / extract of protocol procedure n° 9 .

c *Interrogation ‡ reply sequences*

UF 05 : [PC = 0] [RR = 0] [DI = 0] [SD = $F000^H$] [AP = X]

UF 11 : [PR = 0] [II = 1 & 14] [. . . . zeros . . . .] [AP = X]

where X = the 552 combinations of 2 ONEs & 22 ZEROs and of 2 ZEROs & 22 ONEs
plus the known - the sole - address of the transponder in test in the aircraft.

d *Control*

The non-reply to all 3 x 552 combinations (to UF 05, to UF 11 with II = 1, to UF 11 with II = 14), the correct contents in the replies to the 3 interrogations to be accepted:

DF 05 : [FS = 1] [DR = 0] [UM = 0] [ID = code 7377] [AP = XPDRs address]

DF 11 : [CA = 0, 4, 5 or 6 depending on the capability] [AA = XPDRs address] [PI = II = 1]

DF 11 : [CA = 0, 4, 5 or 6 depending on the capability] [AA = XPDRs address] [PI = II = 14].

Procedure *P 10*

a *Verification*

Altitude Report.

b *Performance specifications*

MS 2.5.1, 3.5.6, 3.17.1 b - MT 5.4.13.4 / extract of protocol procedure n°10.

c *Interrogation ‡ reply sequences*

Intermode C (Mode C / S All-call P1- P3 -P4) ➢ DF 11 reply with AA =XPDRs address ➢

UF 04 : [PC = 0] [RR = 0] [DI = 0] [SD = 0000^H] [AP = the address] ➢ DF 04 reply ➢

UF 04 : [PC = 0] [RR = 20] [DI = 0] [SD = 0000^H] [AP = the address] ➢ DF 20 reply .

Two options, depending on whether or not

a pressure / altitude variator is available

sufficient time for these repeated sequences is acceptable

if YES : test only the “ground altitude” and , if possible to switch off the altitude data, 0000 value

if NO : install the altitude-pressure variator at the relevant captor output and introduce successively a series of defined altitudes such arranged as to give a diversity of bit patterns :
-975 , -600, +600, 2800, 8700, 11800, 12400, 18800, 24300, 24600,
30800, 33400, 36800, 62800, 94800, 100800, 120800 & 1266700 ft .

d *Control*

The correct contents in the replies :

DF 11 : [CA = 0, 4, 5 or 6 depending on the capability] [AA = XPDRs address] [PI = 0].

if YES DF 04 : [FS = 1] [DR = 0] [UM = 0] [AC= x] [AP = XPDRs address]

DF 20 : [FS = 1] [DR = 0] [UM = 0] [AC= x] [MB = 0] [AP = XPDRs address]

x = Gilham conversion of the ground altitude and - 1000 ft if altitude is switched off;

if NO idem with x = each of Gilham conversion of the various altitudes set on the variator.

Procedure *P 11*

a *Verification*

Mode A Report.

b *Performance specifications*

MS 2.5.1, 3.5.6, 3.20.2.11 - MT 5.4.13.4 / protocol procedure n° 11.

c *Interrogation ‡ reply sequences*

UF 05 : [PC = 0] [RR = 20] [DI = 0] [SD = 0000^{H}] [AP = the address] › DF 21 reply

The " pilot " manipulates the control box switches to follow a list of the 66 combinations containing 2 ONEs and 10 ZEROs plus 66 others with 2 ZEROs and 10 ONEs.

d *Control*

The correct replies for each of the successives codes (X) introduced by the pilot :

DF 05 : [FS = 1] [DR = 0] [UM = 0] [AC= X] [AP = XPDRs address]

DF 21 : [FS = 1] [DR = 0] [UM = 0] [AC= X] [MB = 0] [AP = XPDRs address].

Reduced version (if available time is too short) : only the A 1642 code is used.

Procedure *P 12*

a *Verification*

RI Acquisition and Maximum Airspeed.

b *Performance specifications*

MS 3.18.4.25 & 29 , 3.23.1.5 - MT 5.4.13.4 / protocol procedure n° 12.

c *Interrogation ‡ reply sequences*

Depends on whether the XPDR is ACAS-compatible or not

1 - NOT ACAS-compatible:

UF 00 : [000] [RL = 0] [000] [AQ = 0 & 1] [000....000] [AP = the address] › DF 00 replies

2 - The XPDR is ACAS-compatible : the same UF 00 plus

UF 00 : [000] [RL = 1] [000] [AQ = 0 & 1] [000....000] [AP = the address] › DF 16 replies ›

UF 16 : [000] [RL = 0] [000] [AQ = 0 & 1] [000....000] [MU = 0] [AP = address] › DF 00 replies ›

UF 16 : [000] [RL = 1] [000] [AQ = 0 & 1] [000....000] [MU = 0] [AP = address] › DF 16 replies .

d *Control*

The correct replies :

if **1 -** :

DF 00 replies :

[VS =1] [SL = 0] [RI = x] [AC = altitude on the ground] [AP = XPDRs address]

where x = 8 to 14 depending on the max airspeed,when bit AQ was 0

0 when bit AQ was 1.

if **2 -** : (*see MS 3.23.1.5*)

DF 00 replies :

[VS =1] [SL = 0 to 7 depending on the ACAs level or the a/c] [RI = x] [AC = altitude of the ground] [AP = XPDRs address]

where x = 0, 2, 3, 4 , depending on the ACAS capability of the a/c, when bit AQ was 0

8 to 14 , depending on the max airspeed, when bit AQ was 1 .

DF 16 replies : same contents, plus MV filled with zeros.

Remark : More complete tests of the ACAS exchange protocol are executed in Bench test set procedures 31, ...

Procedure *P 13*

a *Verification*

Stochastic Acquisition.

b *Performance specifications*

MS 3.18.4.23 , 3.20 2.2.i - MT 5.4.13.4 / protocol procedure n° 13.

c *Interrogation ǂ reply sequences*

UF 11 : [PR = X] [II = 0] [000 0000 0000 0000 0000] [AP = XPDRs address]

where X is varying from 0 to 15, with 100 interrogations each

1 - with no lockout set

2 - with one lock-out set.

d *Control*

The correct % of replies in each case (with a tolerance of ± 30% for the values other than 99 or 0) :

if **1 -** PR **=**		**%**	>= 99	
	0 & 8			
	1 & 9		= 50	(35 ⇒ 65)
	2 & 10		= 25	(18 ⇒ 32)
	3 & 11		= 12.5	(9 ⇒ 15)
	4 & 12		= 6.2	(4 ⇒ 6)
	other		= 0	

if **2 -** PR =		**%**	>= 99	
	8			
	9		= 50	(35 ⇒ 65)
	10		= 25	(18 ⇒ 32)
	11		= 12.5	(9 ⇒ 15)
	12		= 6.2	(4 ⇒ 6)
	other		= 0	

Procedure *P 17*

a *Verification*

GICB Register Extraction.

b *Performance specifications*

MS 3.21.1.12 (a,b,c & f) - Ref 6 : Mode S Specific Services Manual.

ATTENTION : THE SPECIFICATIONS MAY VARY :

In any case, refer to the latest version of both Mode S Specific Services Manual (see ref. 6) .

c *Interrogation ‡ reply sequences*

UF 04 (or 05) : [PC = 0] [RR = x] [DI = 7] [SD = 0y00] [AP = XPDRs address]

› DF 20 (or 21)replies ;

where x and y (hexadecimal numbers) vary to extract all desired GICB register,

x = sum of 16 + BDS1 subfield

y = RRS subfield = BDS2 subfield.

The present list of registers is

0,5 - 0,6 - 0,7 - 1,0 - 2,0 - 4,0 - 4,3 - 4,4 - 4,5 - 5,0 - 5,1 - 5,2 - 5,3 - 6,0

The transponder must be linked to the corresponding interfaces (ADLP ...) that will input the relevant information in the corresponding register (255 x 56 bit buffer).

d *Control*

The DF 20 (or 21) contains the following fields:

[DF = 20] [FS = 1] [DR = 0] [UM = X] [AC = altitude =0] [MB = message] [AP = XPDRs address]

or

[DF = 21] [FS = 1] [DR = 0] [UM = X] [ID = a/c code A] [MB = message] [AP = XPDRs address] .

For each of the desired register, the MB message rmust be converted following the contents as defined in the Mode S Specific Service Manual.

For example, for register = 4,0 " Aircraft Intention" , the message content is:

bit 1 to 13 selected altiude , in steps of 16 ft (bit 1 = staus, bit 2 = MSB)

bit 14 to 24 selected altiude rate, in steps of 32 ft /mn (bit 14 = staus, bit 15 = MSB)

bit 25 to 35 selected magnetic course(0) / heading(1), in steps of 360/512 deg

(bit 25 = switch (0 or 1), bit 26 = status, bit 27 = sign, bit 28 = MSB)

bit 36 to 47 selected airspeed (0) / mach number (1), in steps of 0.5 kt or Mach 0.004

(bit 36 = switch (0 or 1), bit 37 = status, bit 38 = MSB)

bit 48 to 56 status and selection bits ...

Conversion software have already been developed by EUROCONTROL EEC and could be obtained from this souce. Example of the display of these converted BDS are shown in the EEC note

" Mode-S Specific Services and Data Link Test Bench " (reference 7).

Procedure *P 19*

a *Verification*

AIS, Flight Identification Protocol.

b *Performance specifications*

MS 3.18.4.14 & 27, 3.21.1.13 & 17 - MT 5.4.13.4 / protocol procedure n° 19

+ Ref 6 : Mode S Specific Services Manual.

c *Interrogation ‡ reply sequences*

UF 04 or 05 : [PC = 0] [RR = 18] [DI = 7] [SD = 0000] [AP = XPDRs address]

› DF 20 or 21replies,

where SD contains subfields IIS = 0 , RRS = 0 , the rest = 0 too.

d *Control*

The correct contents of the replies DF 20 or 21

[DF = 20] [FS = 1] [DR = 0] [UM = X] [AC = altitude =0] [MB = message] [AP = XPDRs address]

or

[DF = 21] [FS = 1] [DR = 0] [UM = X] [ID = a/c code A] [MB = message] [AP = XPDRs address]

where the 56 bit message MB is :

[BDS = 2,0] [charac 1] [charac 2] [charac 3] [charac 4] [charac 5] [charac 6] [charac 7] [charac 8]

the characters giving, with ICAO international alphabet n°7, the aircraft's registration (tail number).

Procedure *P 20*

a *Verification*

Capability Report.

b *Performance specifications*

MS 3.18.4.14 & 27, 3.21.1.12 & 17, 3.23.1.2b - MT 5.4.13.4 / protocol procedure n° 20.

ATTENTION : THE SPECIFICATIONS MAY VARY :

In any case, refer to the latest version of both Mode S Specific Services Manual (see ref. 6) and the Mode S subnetwork SARPS.

c *Interrogation ‡ reply sequences*

UF 04 : [PC = 0] [RR = 17] [DI = 7] [SD = 0] [AP = XPDRs address]

where SD contains subfields IIS = 0 , RRS =

[DF = 20] [FS = 1] [DR = 0] [UM = X] [AC = altitude =0] [MB = message] [AP = XPDRs address].

d *Control*

Depending on the level of the transponder , its DataLink possibilities and the evolution of the situation concerning BDS in the future standards.

[DF = 20] [FS = 1] [DR = 0] [UM = X] [AC = altitude =0] [MB = message] [AP = XPDRs address].

4.2 RAMP TEST PROGRAM

4.2.1 Operation

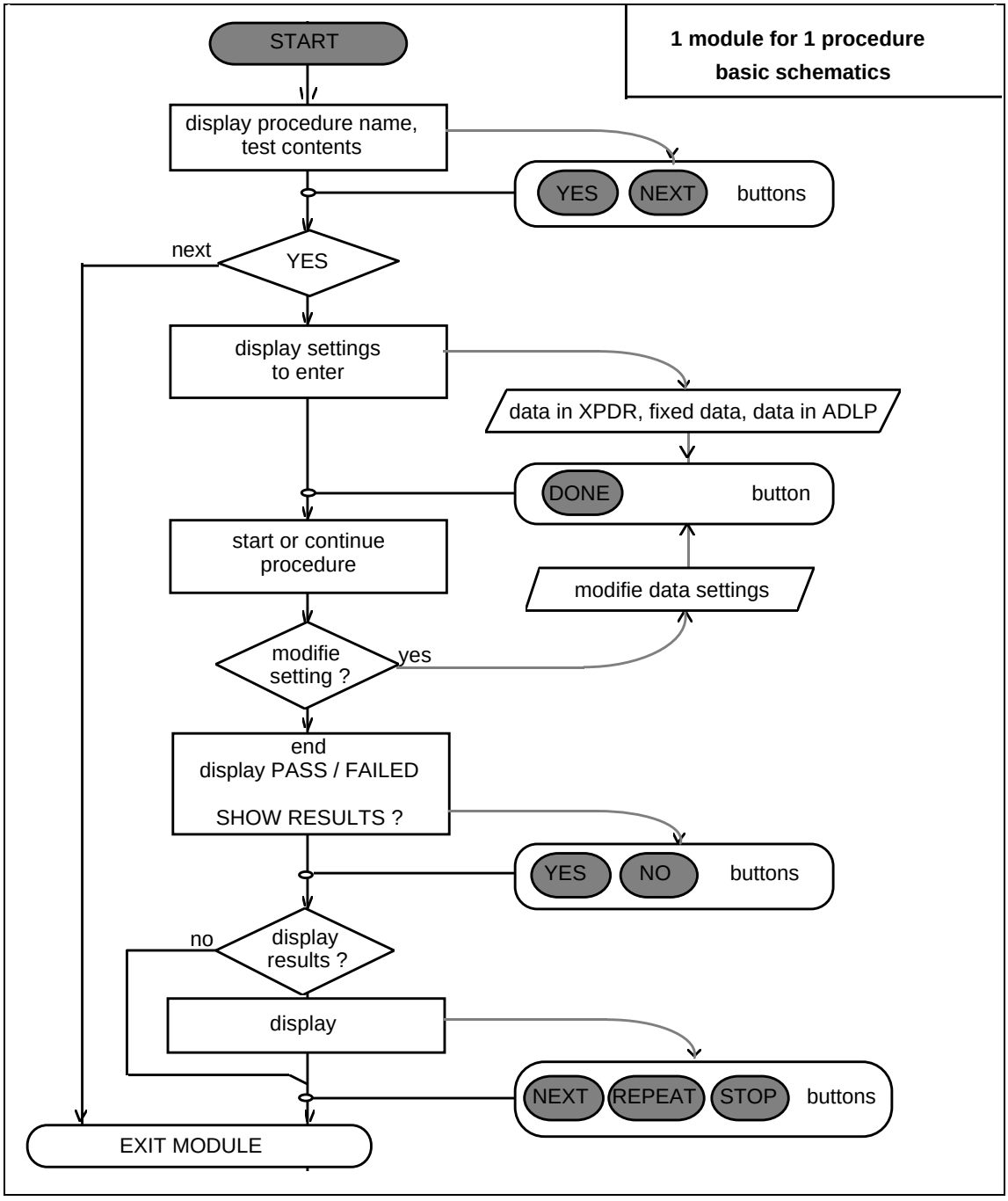
The installation of the test procedures in the Ramp test set is based on a set of successive software modules, that control the sequences developed in paragraph 4.1.

The execution of the tests are dependant of aknowledgement (approval), continue, interrupt or re-start buttons. These buttons may be physically installed in front of the equipment or touch-screen operation.

4.2.2 Modules

Each module controls a succession of displays and waiting periods for any order given by the buttons:

Figure 3 : Module for one procedure



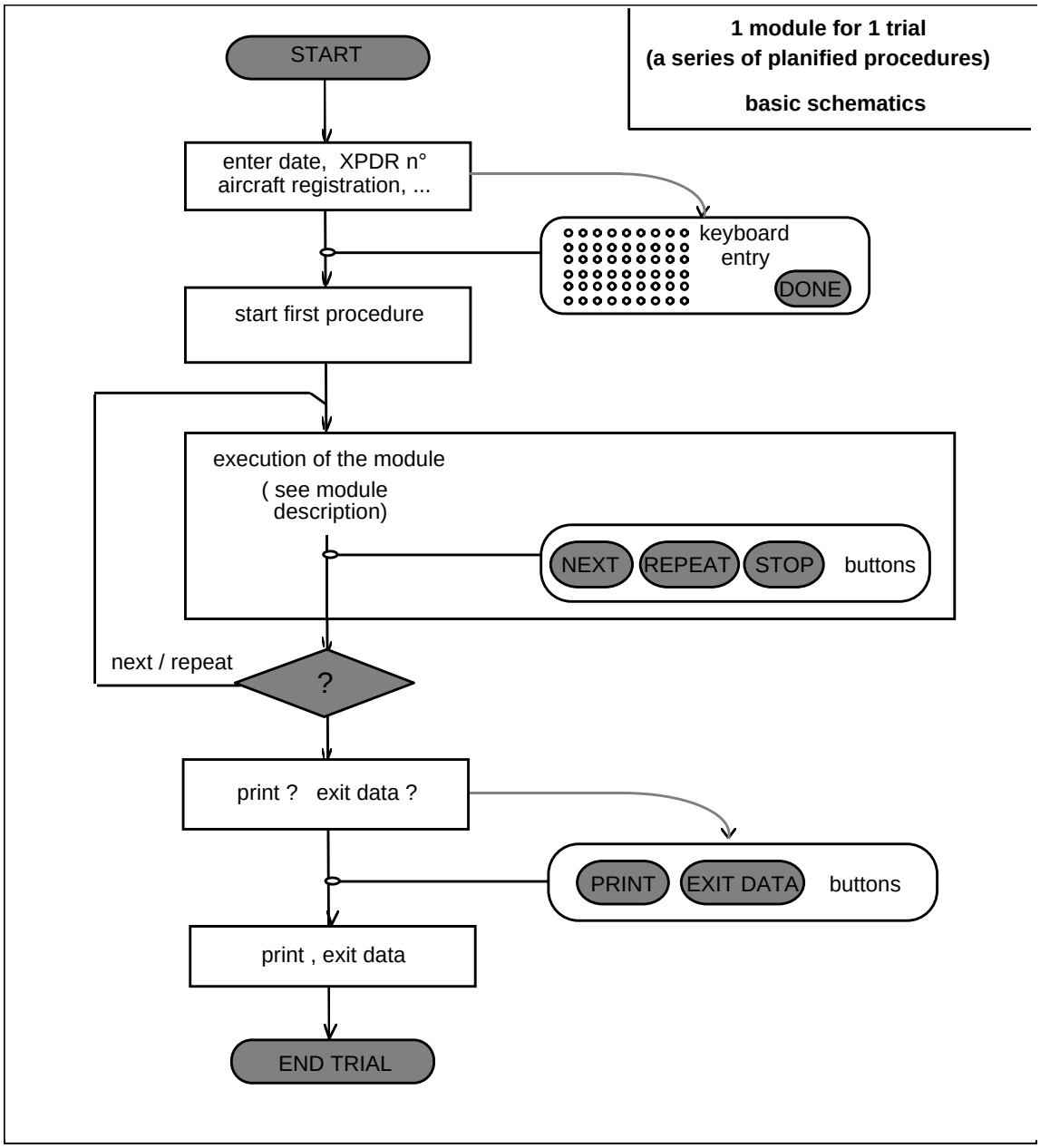
- display the procedure name and tests contents, waite for approval or stop or next procedure;
- display the settings: the data to enter in the transponder via its control box (e.g. the code) or, if applicable, to the external equipment linked to it (ADLP, ...), waite for execution order;
- start of the procedure, stops whenever a new setting has to be applied during the procedure (e.g. change of code), waite for continue order;
- stops at end of testing, display of the information " PASSED " or " FAILED ", wait for order display result or go to the next procedure;
- if result display button has been "pushed", the successive results are presented in the form corresponding to the measurement :

  a data: e.g. Pulse Width = 455 ns (mean of 100 replies, 14 pulses) the tolerances is 350 ⇒ 550 ns
  a X/Y diagram : e.g. reply % *vs.* P3 width with the tolerance areas in grey
  a list of reply messages e.g. DF11, CA = 7, AA = 808080, II = 0 with the text : correct / wrong

after which the system switches over to another module.

4.2.3 Trial Modules

A trial is a planified sequence of procedures defined by the above modules; see this **Figure 4 :**



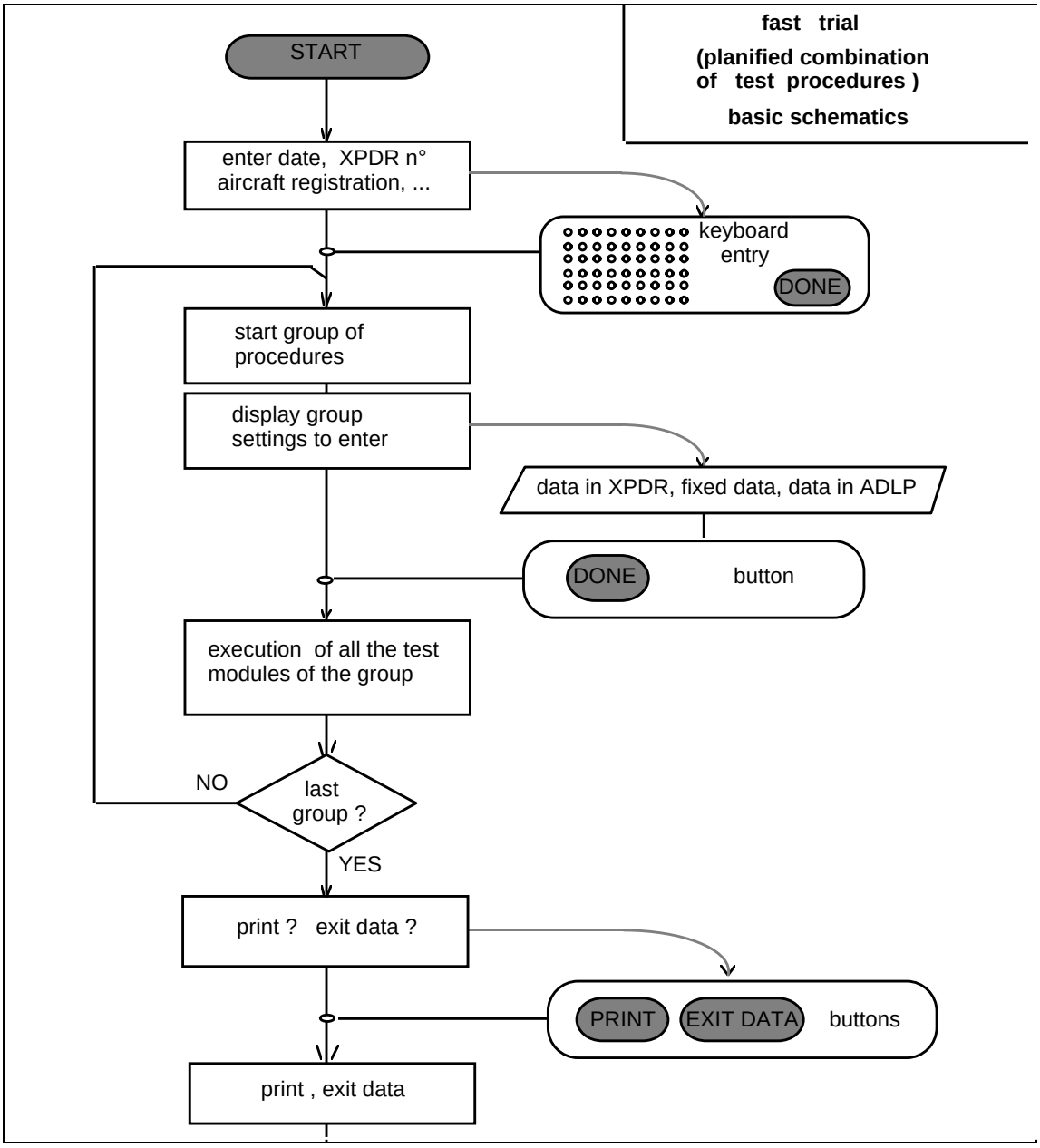
A planned sequence is a list established depending on the user needs (planned maintenance, repair, research, ...)

4.2.4 Fast trials

In order to fasten the trial, one can adopt a succession of test sequences, each sequence being arranged in such a way that the same settings are used for all the tests contained, and no interrupt messages appears during or between tests (like " modify settings ? " or " display results " or " exit data ? "); all data are stored in memory and printed at the end if wanted.

The only interruption in the trial is then the necessary change of settings between two sequences; see the following

Figure 5 : Fast trial (Combination of Procedures)



Example of succession of sequences :

Set code to A 7377 + SPI > sequence P51 - P57 - P75 -P52 ;

change code to 4000 > P52 again ;

change code to 0400 > P52 again ;

change code to 1642 and switch off the altimeter > sequence P53 - P58 - P62 - P66 - P71 - P72 - P77 - P78 - P86 - P87 - P88 ;

print result.

4.2.5 Other Possibilities

The system built for the ramp test set nead some flexibility; one must be able to modify the characteristics of the tests. It is an obligation to allow

- the evolution of maintenance rules, these being adapted to the ATC SSR problems and to manufacturing changes,
- the research and developments of administrations and airliner maintenance services,
- the easy building of the laboratory test set variant.

This implies the “availability” of the modules: one must be able to access the measurement parameters (number of iterations, succession of Mode S formats, etc...), with the sole limitations that only authorised technicians may control these elements and that in any case, the default values are set back for the usual operator. Unauthorised values (too large, ..., unpossible message subfield, ...) for the test parameters are announced to the operator and the system wait for new entry.

4.2.6 Results Management

4.2.6.1 Memory

All results are automatically written in memory; it contains the date, the transponder under test references (serial number, aircraft regitration, Mode S address), each successive test protocol (n°, name), the conditions of the test (settings), the resulting data (whatever the form) even if no display was asked by the operator during the test.

To avoid to the risk of field failure, hard disk should be replaced by any other memory system.

4.2.6.2 Result transfer

The contents of the memory must be transferable by any actual means (floppy disk or equivalent, GPIB bus, RS232, ...) to another computer base or local network. Printer output is required.

4.2.7 Autotest

The system must contain an autotest device, that is automatically launched before any operation starts.

This autotest verifies the input and output of the system and can control the exactness of the measurements through a reference transponder.

It must be possible to introduce the distance ramp tool -- aircraft antenna before starting the tests, in order to the apply the corresponding time delay correction.

4.3 TECHNICAL DATA

The equipment must be able to generate all the tests described in the test lists above and therefore must have the following capacities:

4.3.1 Output (Uplink)

- Two channels (to allow in the bench variant, the diversity measurements)
- frequency : 1020 - 1040 Mhz, steps of 0.2 Mhz
- power : for measurements at 2 to 25 (or 15) meters: up to 37 or 44 dBm (5 or 25 W)
  at output of antenna, in steps of 0.5 dB
  difference between channels : up to . . . . .
- pulse : miminum width 250 ns, steps of 25 ns (or shorter),
  with intervals of 200 ns between one pulse decay and the next pulse rise
  pulse rise and decay times (respecting ICAO Annex 10)
  DPSK modulator for uplink P6 pulses (idem)
- pulse sequences : all Mode A, C, Intermode A, C
  that is, all combinations of two following P1, P2, P3, P4 trains;
  Mode S UF / DF 00, 04, 05, 11, 16, 17, 20, 21, 24 with any field and subfield contents;
  time delays up to 30 sec (use in lockout tests if these test are added)
- repetition rate : PRF 1 to 100 hz in Mode S, to 2000 hz in the other Modes
- physical output : both channels to connecting cable (connector "N")
  one channel to antenna 10 W maximum.
- antenna : directional, on a tripod, to connecting cable (connector "N").

4.3.2 Input (Downlink)

- Two channels (to allow in the bench variant, the diversity measurements)
- frequency : 1070 - 1110 Mhz, resolution 0.01Mhz
- power : up to 0.1W (17 dBm) at input to antenna, with a resolution of 0.5 dB
- pulse : miminum width 200 ns, resolution 25 ns (or shorter)
  with intervals of 200 ns between one pulse decay and the next pulse rise
  pulse rise and decay times measurable.

4.3.3 Display

- Active matrix for confortable external natural light
- 9 inch screen 800 x 600 pixels
- either 20 lines of text or diagram X/Y
- dialog windows with on-screen buttons, data result presentation
- powers : peak pulse value, mean values (as defined in the procedure paragraphs), in dB & in W
  altitude available in feet.

4.4 TESTING ENVIRONMENT

- The equipment will be used essentially on external.
- Power input : 90 to 240 V , 45 - 440 hz
- Temperature : 0 to +55°C in operation
- -40 to +70°C storage
- Humidity : 95 %
- Standard shock proof.

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5 LABORATORY TEST BENCH

5.1 PROCEDURES ANALYSIS

see next version of this note

5.2 BENCH TEST PROGRAM

see next version of this note

5.3 TECHNICAL DATA

see next version of this note

5.4 TESTING ENVIRONMENT

see next version of this note

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6 REFERENCES

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EUROCONTROL DED3 information paper for the SSGT meeting October 1996

Ref 2 & 3 . GTVS : Ground Transponder Verification Verification

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1) INTERSOFT ELECTRONICS Olen, Belgium
2) THOMSON-CSF/SDC Meudon-la-forêt, France

Ref 4 . . . STFTV Surveillance Team / Task Force on Transponder Verification
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Ref 5 . . . A Field Study of Transponder Performance in General Aviation Aircraft
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Ref 6 . . . Mode S Specific Services Manual

ICAO Doc 9688-AN/952 June 1997

Ref 7 . . . Mode S Specific Services and Data link Test bench

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